UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PROGRESS REPORT I: PRELIMINARY INVESTIGATIONS IN HYDRAULIC LABORATORY OF FLOCCULATING AGENT NO. 1

Hydraulic Laboratory Report No. Hyd-405

DIVISION OF ENGINEERING LABORATORIES

COMMISSIONER'S OFFICE
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Laboratory Report No. Hyd-405
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Subject: Progress Report I: Preliminary Investigations in Hydraulic Laboratory of Flocculating Agent No. 1

Introduction

During the period of August and September 1955, a series of tests were made on flocculating Agent No. 1. The tests were conducted in the Bureau of Reclamation Hydraulic Laboratory at the Denver Federal Center.

The purpose of the tests was to determine the feasibility of using a flocculating agent as an aid in settling out suspended sediment.

The tests were performed in two series. In the first series, three different types of sediment were tested to determine the amount of agent needed to flocculate various concentrations of suspended sediment under quiescent conditions. The second series of tests were performed in a 1-foot-wide by 1-1/2-foot-deep by 30-foot-long flume to determine if the treated sediment would flocculate when the water was flowing. Figure 1 shows the test equipment used in both series.

The initial tests on the flocculating agent were performed in the laboratory on three sediment samples from canals in the Middle Rio Grande area representing material with varying amounts of clay, sand, and silt. The sediment samples tested were numbered as follows: 23M4, 23M7, and MC10. No size analysis of the MC10 material was made, but the 23M4 contained 54 percent sand and 46 percent silt to clay and the 23M7 contained 8 percent sand and 92 percent silt to clay.

Testing Procedure

A testing procedure was established by trial and error in order to obtain the best results; once this procedure was set it was followed in all subsequent tests.

Testing procedure:

(1) Weigh amount of test sediment to provide desired sediment concentration.

(2) Mix sediment in small amount of water to insure that all clay particles go into suspension.

(3) Mix in electric mixer for 3 minutes.

(4) Place in bottom withdrawal tube and add water until tube is filled to 500 cc mark.

(5) Turn tube end for end until solution is uniformly mixed.

(6) Place 1/3 of flocculating agent in tube and turn tube end for end 3 times.

(7) Repeat No. 6 two more times. This insures good distribution of the flocculant and also provides the time and turbulence necessary for floc buildup.

(8) Place tube in rack and withdraw approximately 50 cc of sample into separate beakers at 45 seconds, 2 minutes, 5 minutes, and 10 minutes.

(9) Place beakers in electric oven overnight to evaporate water.

(10) Determine amount of sediment that settled out during each time interval by weighing dried sample.

The three sediment samples were tested at 2, 1, and 1/2 percent sediment concentrations. For each sediment concentration, 3 different percentages of flocculating Agent No. 1 were tried, as well as one test without a flocculating agent. The concentration of the flocculating agent is listed as "pounds per ton;" this refers to pounds of flocculant per ton of suspended solids.

Test Results

The results of each test have been plotted and are shown on the attached graphs. Although the results are not statistically correct due to the fact that only one run was made for each test condition, the tests have established an approximation of the effectiveness of the flocculating agent. Further tests would be helpful in stabilizing the curves but would also require at least another 5 or 6 days of testing.

Test Series No. 1. The curves indicate that under quiescent conditions 80 to 90 percent of the sediment settles out without the addition of the flocculating agent. The addition of a very small amount of flocculating agent increases the amount of settling; in the case of the high sand content sediment (23#4), the quantity settled out increased to 95 percent, while the low sand content sediment increased to about 98 percent settled out. The MC10 sediment showed an increase from 90 percent settled out to about 98 percent settled out. These percentages are based on a 10-minute settling time, Figures 2, 3, and 4.

A plot of the amount of sediment settled out versus time is shown on Figures 5 to 13, inclusive. The plots indicate that the amount of sediment settling out increases with time and also increases as the strength of the treatment increases. There also seems to be a trend in all of the graphs indicating that for equal treatment levels, or strength of flocculating agent, a higher percentage of the suspended sediment will be removed when there is more in suspension.

To summarize:

(1) In 10 minutes 80 to 90 percent of the sediment settled out without the use of a flocculating agent.

(2) A very small amount of the flocculating agent increased the percentage of sediment that settled out as follows: in the case of sandy sediment to 95 percent, and in the case of clayey sediment to 98 percent.

(3) The percentage of sediment that settles out increases as the concentration of the suspended sediment increases.

Test Series No. 2. The second series of tests were performed in the 1-foot-wide, 30-foot-long recirculating flume. These tests were exploratory in nature due to the limitations of the flume. Five tests were made in the flume; the first two were mainly concerned with determining methods of suspending the sediment, adding the flocculating agent, and measuring the effectiveness of the agent.

In all five tests the method of adding the sediment to the flowing water was the same. The amount of needed sediment was determined by a percentage of the weight of the water in the flume; since the amount of water in the flume was 103 cubic feet or about 6,430 pounds, enough sediment was added to give about a 1 percent suspended sediment concentration by weight. Also added to the flume water were

enough chemicals to represent a water hardness similar to that of the Middle Rio Grande. The chemicals added to 103 cubic feet of water were:

490 grams of $NaHCO_3$
29.1 grams of $MgSO_4$
329 grams of $CaSO_4$
168 grams of $CaCl_4$
later increased to 378 grams

After several minutes of circulation, a sample of the water was taken so that its hardness could be determined.

The sediment (similar to MC10 in previous tests) was thoroughly mixed into a slurry before it was added to the flume water; as the sediment slurry was added to the flume water, the velocity of the flume flow was increased in order to keep as much of the sediment as possible in suspension; after the sediment was completely mixed in the flume, the velocity was reduced to about 0.75 foot per second.

In the first test two 50-ml samples of water were taken from the downstream end of the flume at 10-minute intervals, one of the samples was obtained near the surface of the flow and the other from mid-depth. The samples were then evaporated and the amount of residue weighed and used as a measure of the amount of suspended sediment. These amounts are referred to as the percent of the suspended solids in the water.

Flume Test No. 1--Two runs were made on the first flume test. In the initial run the first sediment sample showed about 0.4 percent sediment in both the surface sample and the deep sample. The flocculant was added about 23 minutes after the first sediment sample; 440 cc of 0.2 gram/liter flocculant solution were added to the flume flow over a 1-1/4-minute period of time. Ten minutes after the flocculant was added, sediment samples were again obtained, and at the end of an additional 10 minutes a third sample was taken. The second sediment sample showed that the suspended solids had reduced to about 0.30 percent; the third sample showed a concentration of 0.30 percent for the deep sample, but the surface sample had reduced to about 0.24 percent suspended sediment. At this time an additional 440 cc of 0.2 gram/liter flocculant were added to the flow. Three additional samples taken at 10-minute intervals showed that the suspended sediment in the surface sample stayed constant at a concentration of about 0.24 percent, the samples of the deep flow showed an increase to about 0.36 percent for the first two samples, and the last sample decreased to about 0.30 percent. These results are shown on Figure 14.

For the second run of the first flume test two changes were made in the test procedure. The flocculant was added by a Clarkson feeder at a constant rate depending on the water velocity. The second change was to obtain sediment samples at both the upstream and downstream ends of the flume. The size of the samples was still 50 ml, and they were obtained at the surface and at mid-depth.

For the second run the sediment was resuspended and the flow velocity reduced to about 0.2 foot per second. The initial suspended sediment concentrations were as follows:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.22%	0.18%
Mid-depth	.28%	.34%

Ten minutes later the concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.22%	0.16%
Mid-depth	.24%	.22%

The addition of the flocculant was started at the rate of 32 ml per minute, the strength was 0.005 percent, a very weak solution. After 10 minutes the sediment concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.20%	0.18%
Mid-depth	.20%	.20%

After another 10-minute period the concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.18%	0.14%
Mid-depth	.20%	.26%

These two runs of the first test indicated that the flocculant would accelerate the rate or increase the amount of settling, but the improvement was rather small, Figure 14.

Flume Test No. 2.--Before starting the second test the flume was cleaned and fresh water placed in it, also the same amounts of chemicals were added in order to increase the hardness. Eighty-six pounds of sediment similar to the MC10 was mixed into a slurry and added to the flume water. The flow in the flume was kept at about 3.25 feet per second velocity until the silt was added, then the velocity was reduced to about 0.14 foot per second. The first sediment sample was obtained with the velocity at 3.25 feet per second.

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.94%	0.82%
Mid-depth	.90%	.96%

Twenty minutes after the velocity was reduced to 0.14 foot per second another set of samples was taken:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.68%	0.52%
Mid-depth	.72%	.76%

After a time interval of 11 minutes the third sample was taken:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.62%	0.44%
Mid-depth	.66%	.70%

After this sample had been taken the flocculant feeder was started at the rate of 300 cc per minute with a strength of 0.01 pound of flocculant per ton of solids. There was no visible flocculation so the treatment rate was increased to 500 cc per minute and finally to 750 cc per minute. This produced a slight flocculation, but not sufficient; therefore, the strength of the treatment was further increased until it was equivalent to about 0.10 pound of flocculant per ton of solids, assuming a silt load of about 0.8 percent.

After a time interval of about 33 minutes from when the flocculant was first added a final sediment sample was obtained:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.34%	0.16%
Mid-depth	.42%	.36%

When the results of the second test are plotted, Figure 15, the plot indicates that the flocculant increased the amount of sediment that settled out. The curves showed that the amount of suspended sediment was leveling out or tending to remain constant but that when the flocculant was added the curves steepened, indicating that more sediment was settling out.

Flume Test No. 3.--For the third flume test the flume was again cleaned and fresh water added; the same chemicals as before were added in order to increase the hardness of the water. A series of baffles was placed at the upstream end of the flume in order to improve the turbulence necessary for complete mixing. Another test change was to induce the flocculant into the flume flow through three different sources at the upstream end of the flume rather than just one source. Eighty pounds of silt was slurried and mixed with the flume water.

For this test 40 pounds of MC2 sediment and 40 pounds of MC4 sediment were used; from appearances the MC2 sediment seemed to have a very high clay content, and the MC4 was quite sandy. Tests performed with the bottom withdrawal tubes gave the following results for a 10-minute time interval (Figure 16):

MC2 sediment--No flocculant, 59.2 percent settled out
Flocculant at rate of 0.044 pound/ton, 90.2 percent settled out

MC4 sediment--No flocculant, 82.7 percent settled out
Flocculant at rate of 0.032 pound/ton, 96.6 percent settled out.

After the silt slurry was mixed in the flume water the velocity was reduced to about 0.10 foot per second. The first sediment sample gave these results:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.72%	0.54%
Mid-depth	.68%	.62%

Ten minutes later the concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.58%	0.48%
Mid-depth	.62%	.70%

The flocculant feeder was started after this sampling. The strength of the flocculant was 0.05 pound per ton of solids and the rate of feeding was 200 cc per minute.

Ten minutes after the flocculant was started the suspended sediment concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.52%	0.22%
Mid-depth	.58%	.58%

After another 10-minute time interval the concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.42%	0.12%
Mid-depth	.42%	.20%

During this period there was visible flocculation in the stream flow and the flocs were settling almost vertically, however, the appearance of the water between the flocs was still cloudy.

The rate of adding the flocculant to the flume was increased to 250 cc per minute. Ten minutes later the sediment concentrations were:

	Percent of suspended sediment	
	Upstream	Downstream
Surface	0.24%	0.16%
Mid-depth	.24%	.24%

The results of this test are shown on Figure 17.

Flume Test No. 4.--All of the preceding tests appear to give more or less erratic results when plotted on graph paper with the suspended sediment concentration as the ordinate and time as the abscissa, but without exception the trend is for the suspended sediment concentration to become smaller with time. The amount of reduction of the suspended sediment was greater when the flocculant was added to the flow than when there was no flocculant added. One test was performed in which a 4-hour run was made with no flocculant added to the flow. A very small amount of suspended sediment, same material as used in Flume Test No. 3, was in the flow at the start of the test.

The mid-depth sediment concentrations for Flume Test No. 4 were:

	Percent of suspended sediment	
	Upstream	Downstream
Start	0.46%	0.40%
After 50 min	.28%	.32%
After 1 hr 50 min	.30%	.26%
After 3 hr	.26%	.26%
After 3 hr 50 min	.26%	.26%

The results are also shown on Figure 18.

Flume Test No. 5.--For the fifth flume test the only change was to admit the water at the upper end of the flume through a sluice gate. An hydraulic jump formed just downstream from the gate at the same place that the flocculant was introduced. The jump was comparatively short but its mixing action permitted a much better floc to form. The results of the tests are shown in the following chart as well as on the graph of Figure 19.

		Percent of suspended sediment	
		Upstream	Downstream
Start	Surface	0.74%	0.56%
	Mid-depth	.80%	.81%
After 10 min	Surface	.71%	.65%
	Mid-depth	.72%	.74%
After 20 min	Surface	.65%	.62%
	Mid-depth	.66%	.69%
After 30 min	Surface	.61%	.54%
	Mid-depth	.70%	.68%

The addition of the flocculant was begun 35 minutes after the start of the test. During 35 minutes 0.09 gram of the flocculant mixed in 3,100 cc of water were added to the flume flow. During the period the flocculant was being added, the suspended sediment concentrations were as follows:

		Percent of suspended sediment	
		Upstream	Downstream
After 45 min	Surface	0.63%	0.62%
	Mid-depth	.65%	.64%
After 55 min	Surface	.62%	.48%
	Mid-depth	.60%	.60%
After 65 min	Surface	.45%	.27%
	Mid-depth	.44%	.49%

Even after the flocculant was not being added the percentages of suspended sediment continued to diminish:

		Percent of suspended sediment	
		Upstream	Downstream
After 75 min	Surface	0.35%	0.33%
	Mid-depth	.38%	.36%
After 85 min	Surface	.33%	.31%
	Mid-depth	.31%	.37%
After 95 min	Surface	.31%	.30%
	Mid-depth	.33%	.35%
After 105 min	Surface	.28%	.27%
	Mid-depth	.32%	.31%

The graph of Figure 19 shows the effect of adding the flocculant quite plainly. The amount of suspended sediment had almost attained equilibrium when the addition of the flocculant was started. After the flocs had a chance to form the quantity of suspended sediment started to diminish and continued to do so until after the flocculant was stopped, at which point the amount of suspended sediment again attained an equilibrium state.

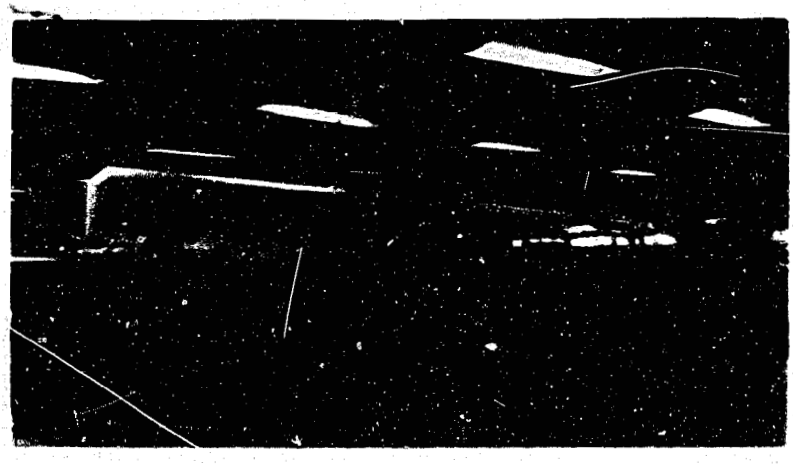
Conclusions and Recommendations

After analyzing the results of the flocculant tests the following conclusions and recommendations are presented:

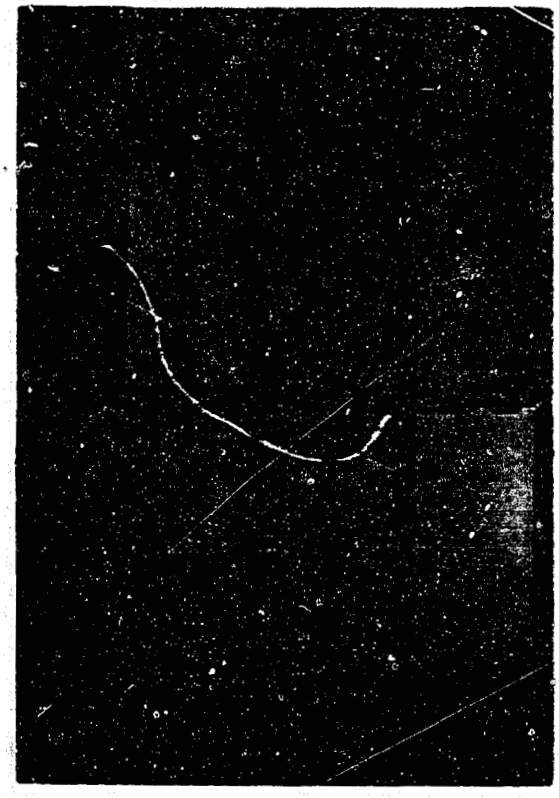
(1) The flocculant used in these tests was successful in accelerating and improving sediment removal.

(2) The flume tests showed that better flocculation was obtained when some turbulence was introduced. Since it is doubtful if maximum mixing and flocculation was obtained in any of the flume tests, further laboratory tests should be made to determine a relationship between turbulence level and most effective time of floc buildup to give the maximum amount of settling. Equipment which was used on a previous sedimentation study can possibly be used to give this relationship.

(3) After successful laboratory tests are made, one or more field studies will be necessary in order to correlate the laboratory results with prototype use.



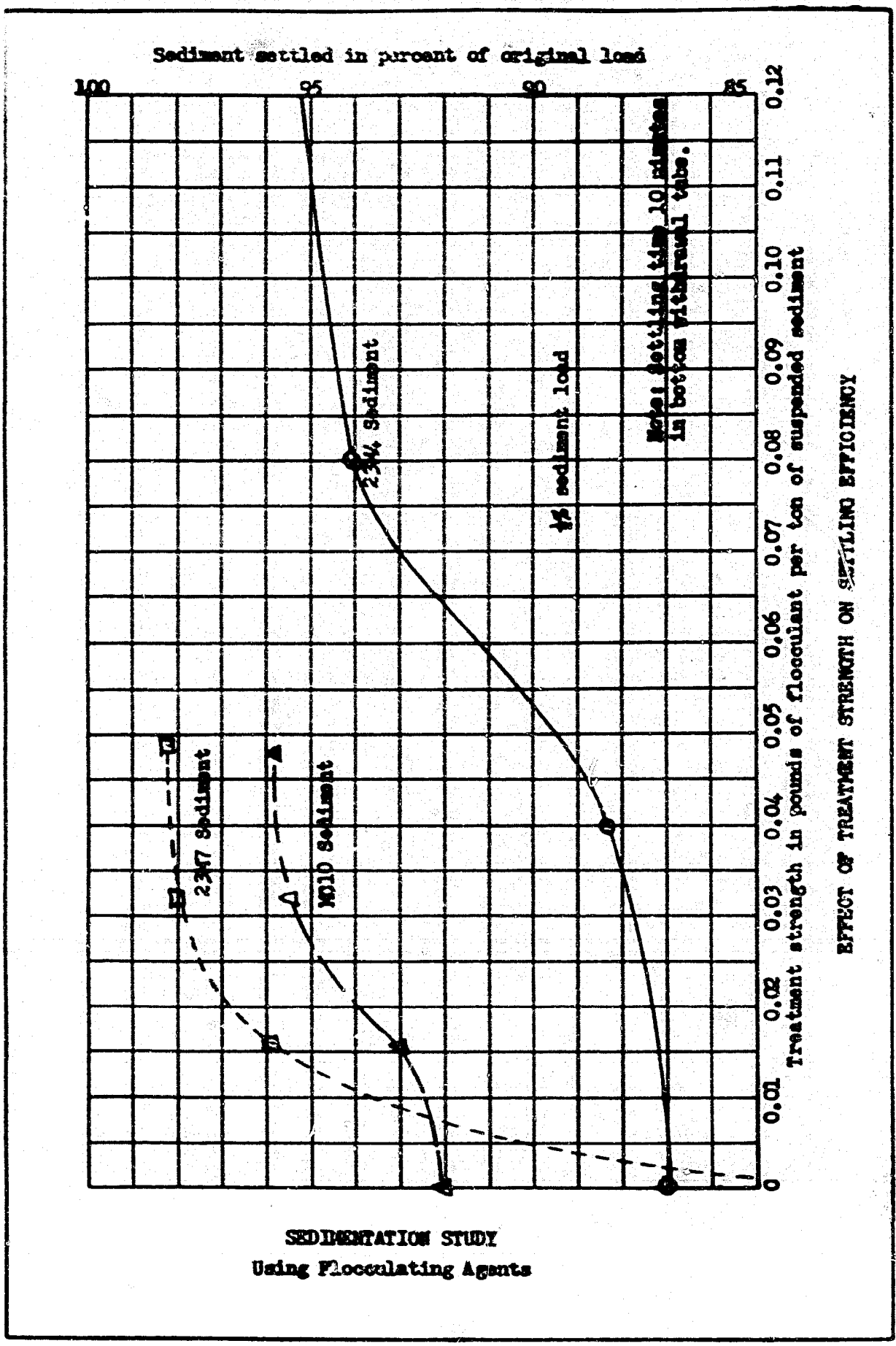
A. General view showing the 1-foot by 1½-foot by 30-foot long recirculating flume used in Test Series No. 2.



B. Bottom withdrawal tubes used in Test Series No. 1.

SEDIMENTION STUDY
Using Flocculating Agents
Test Equipment

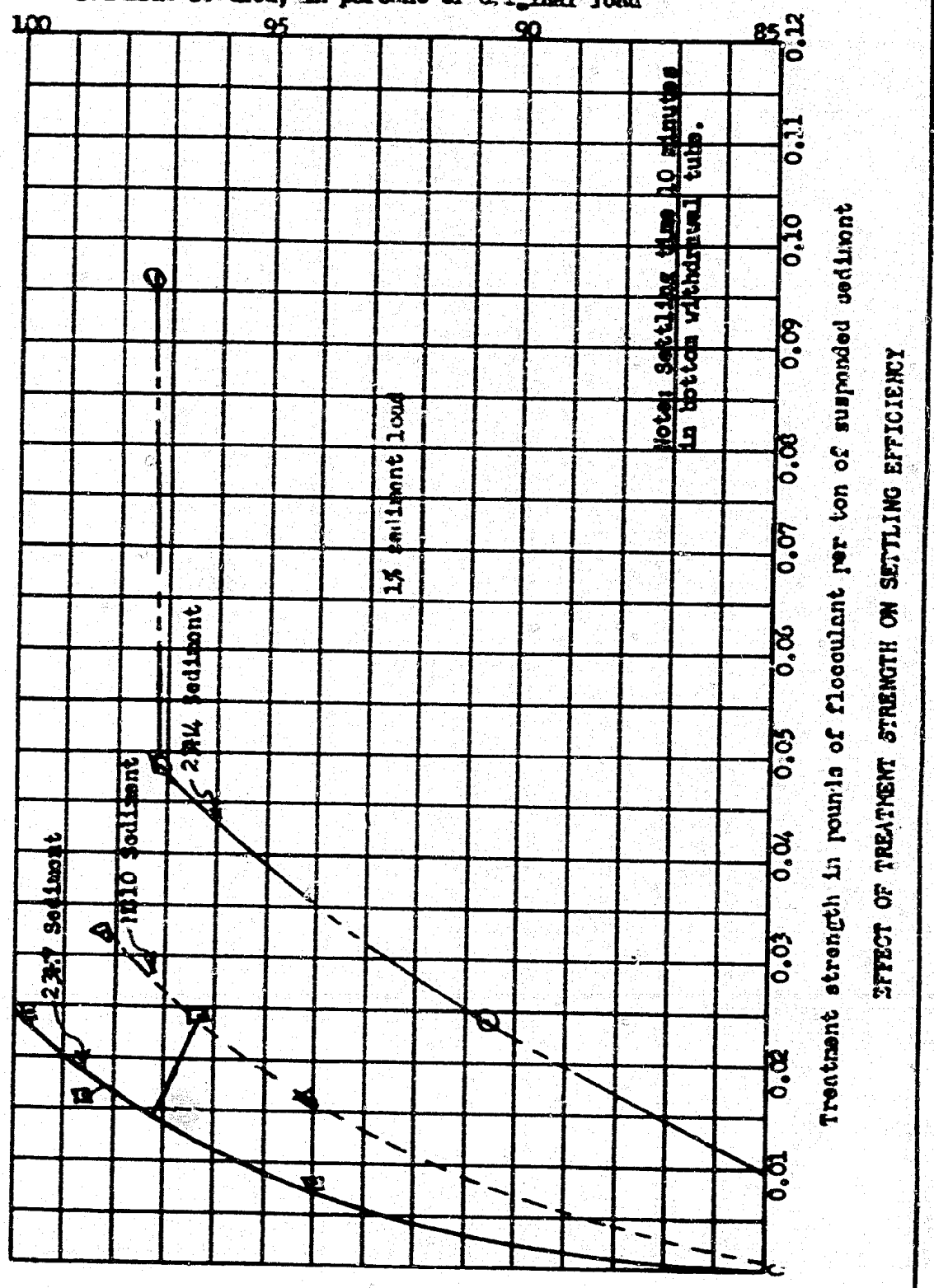
FIGURE 2



SEDIMENTATION STUDY

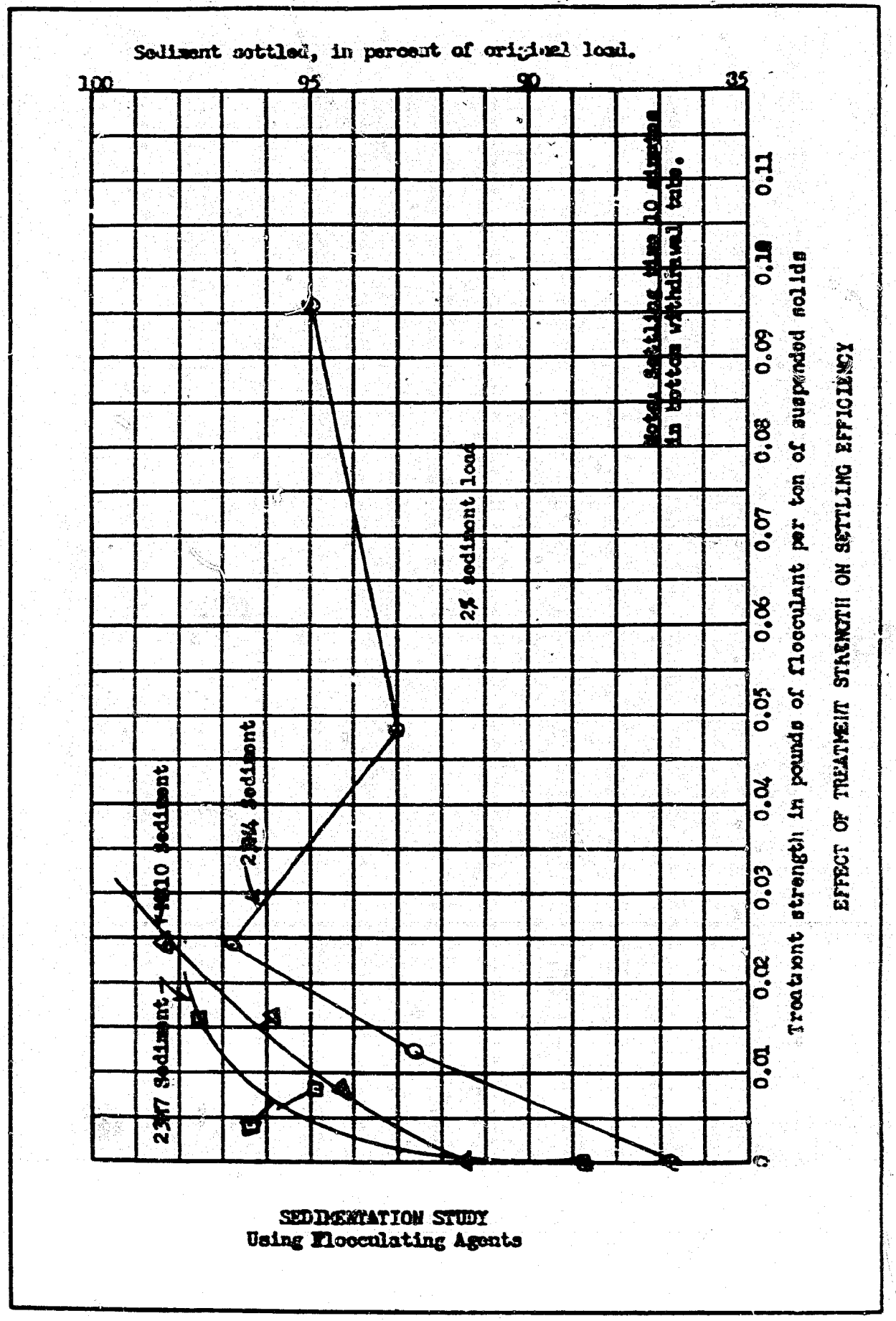
Using Flocculating Agents

FIGURE 3



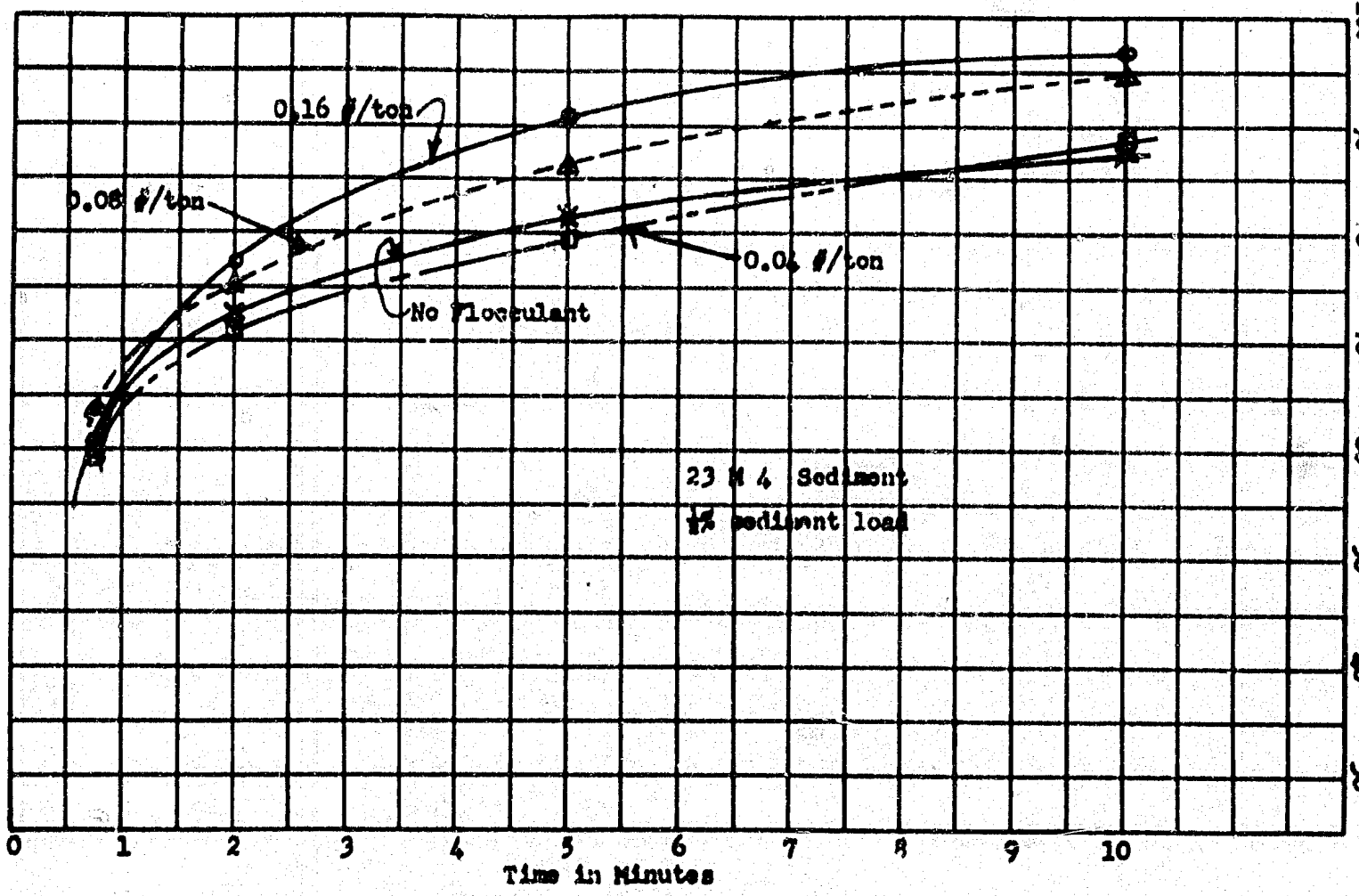
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 4



SEDIMENTATION STUDY
Using Flocculating Agents

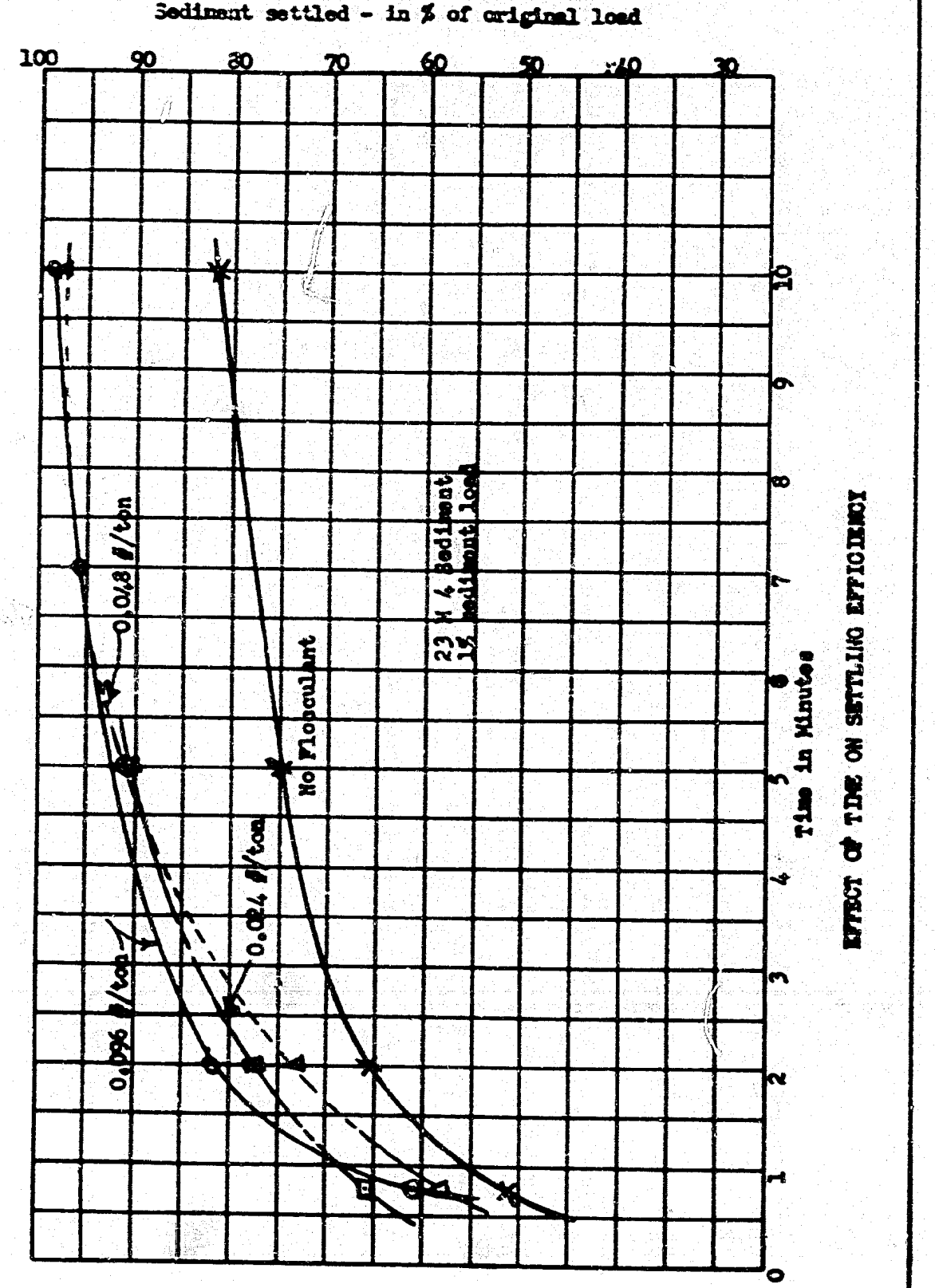
FIGURE 5



SEDIMENTATION STUDY
Using Flocculating Agents

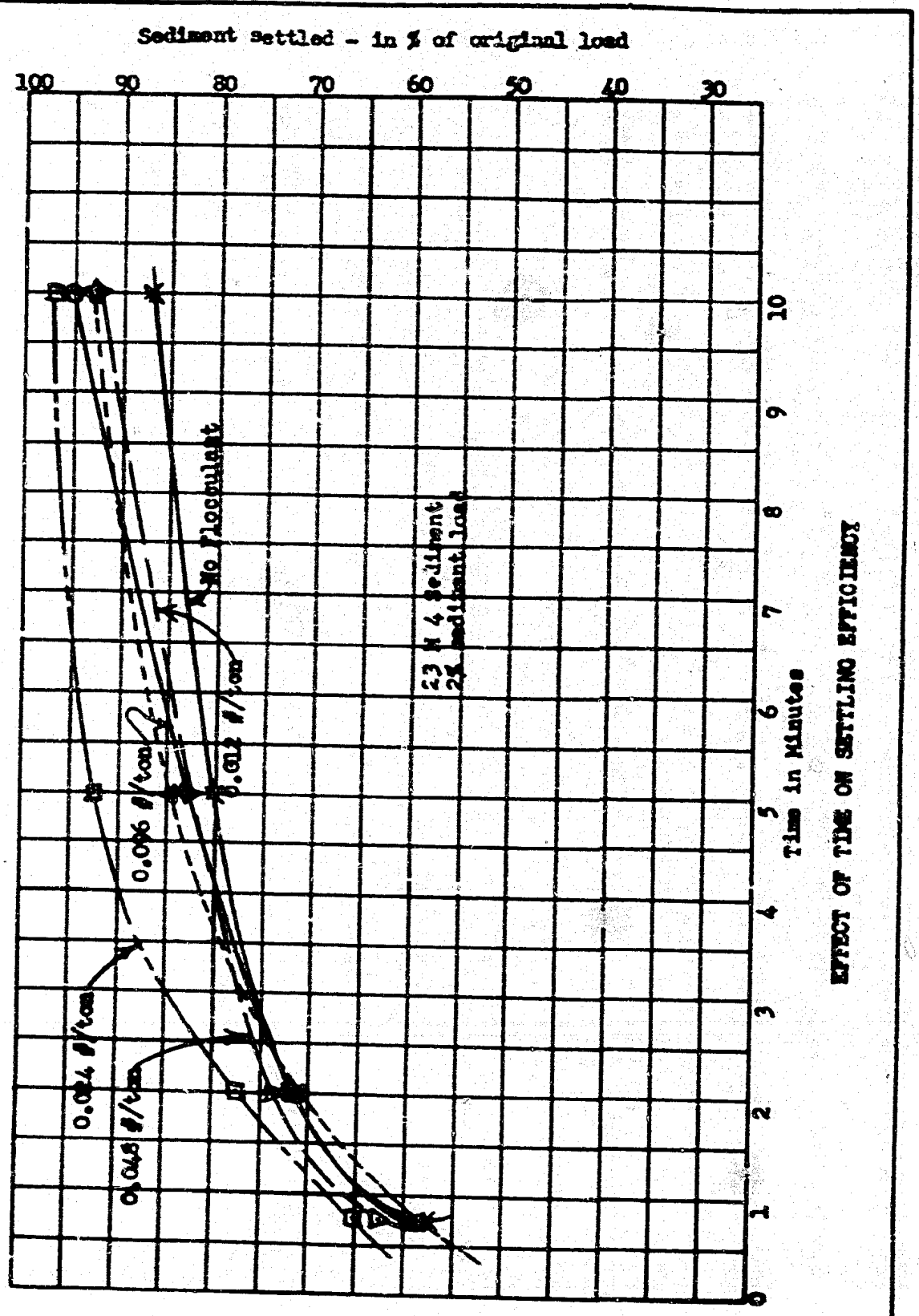
EFFECT OF TIME ON SETTLING EFFICIENCY

FIGURE 6



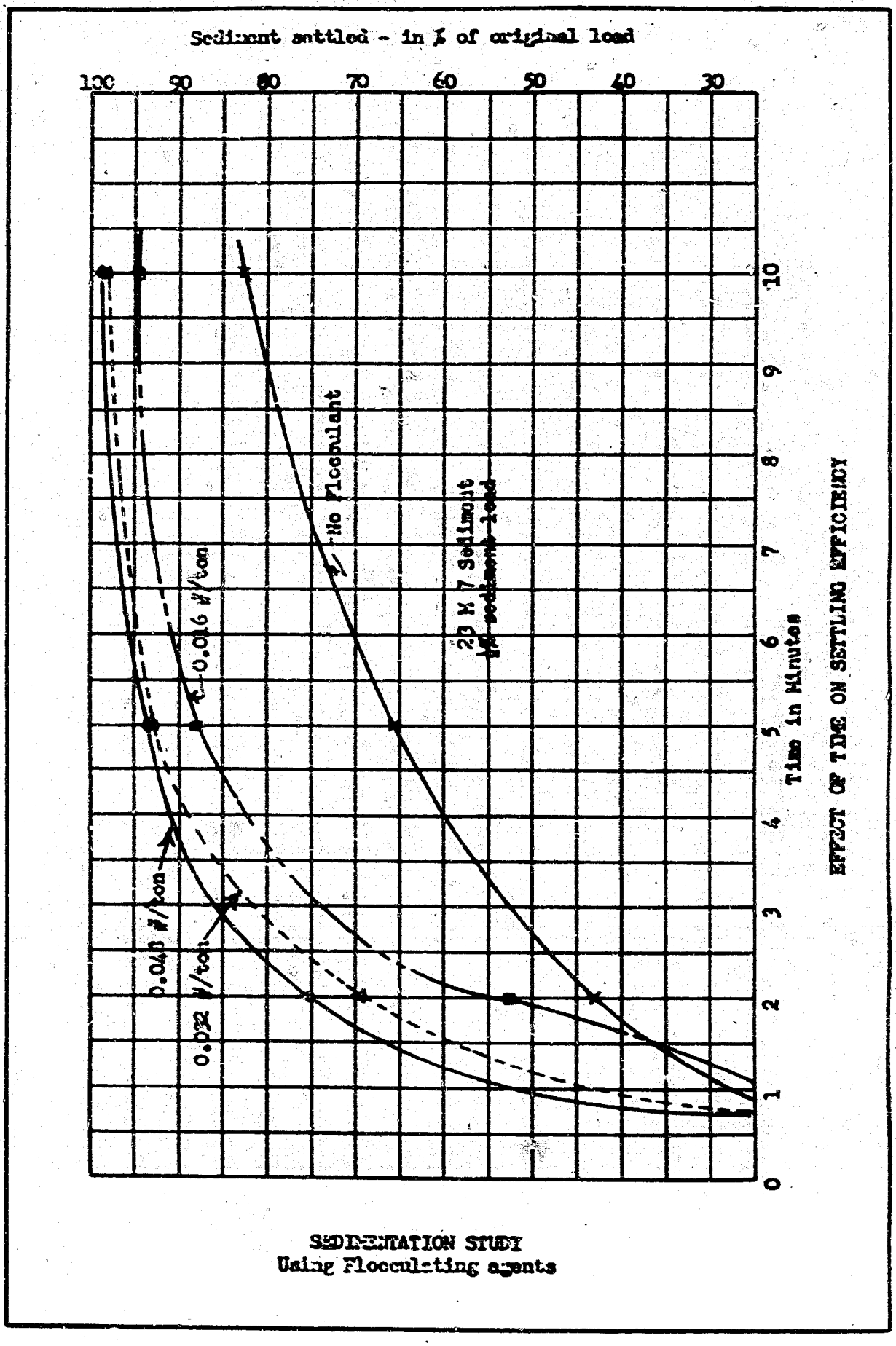
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 7



SEDIMENTATION STUDY
Using Flocculating Agents

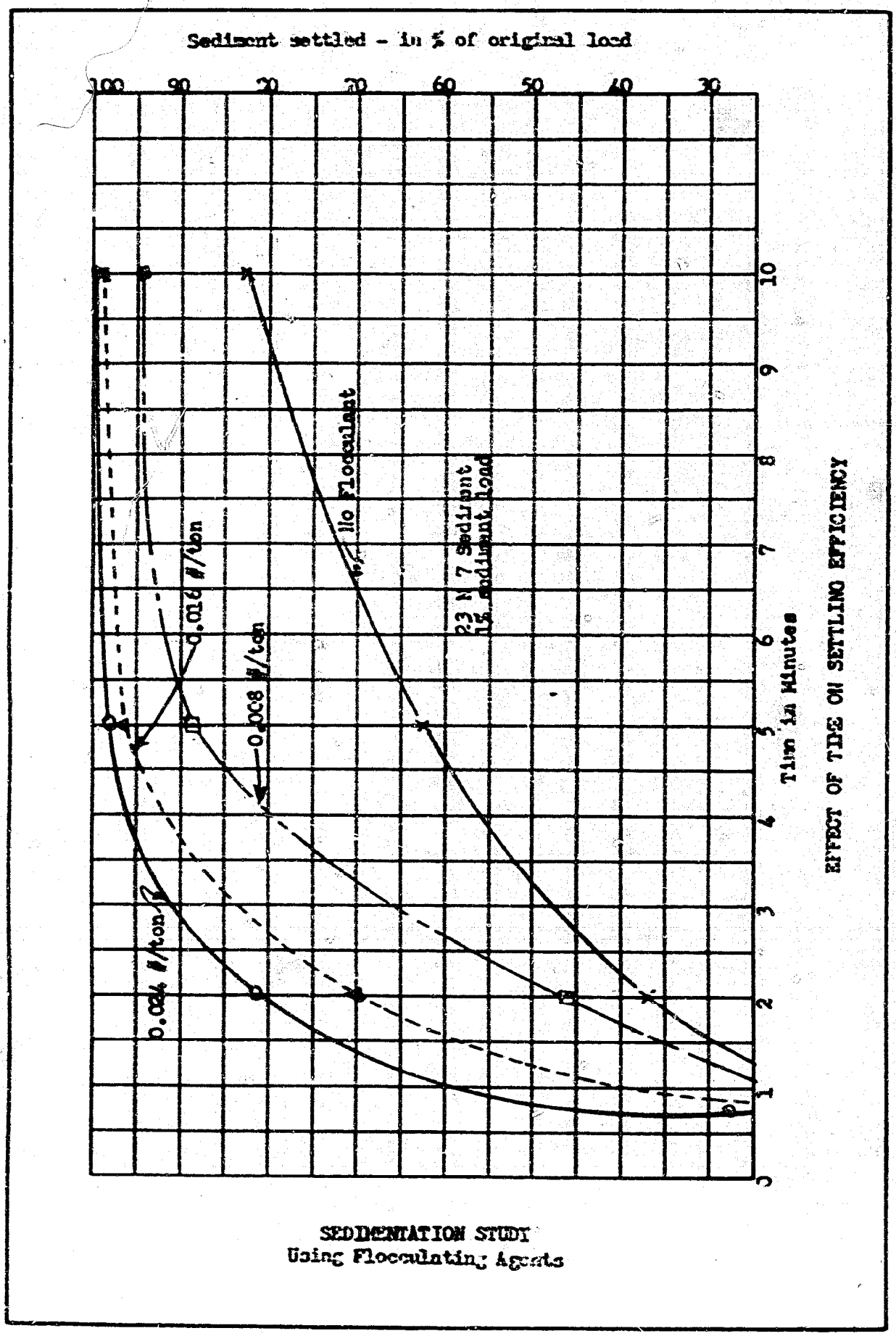
FIGURE 8



EFFECT OF TIME ON SETTLING EFFICIENCY

SEDIMENTATION STUDY
Using Flocculating agents

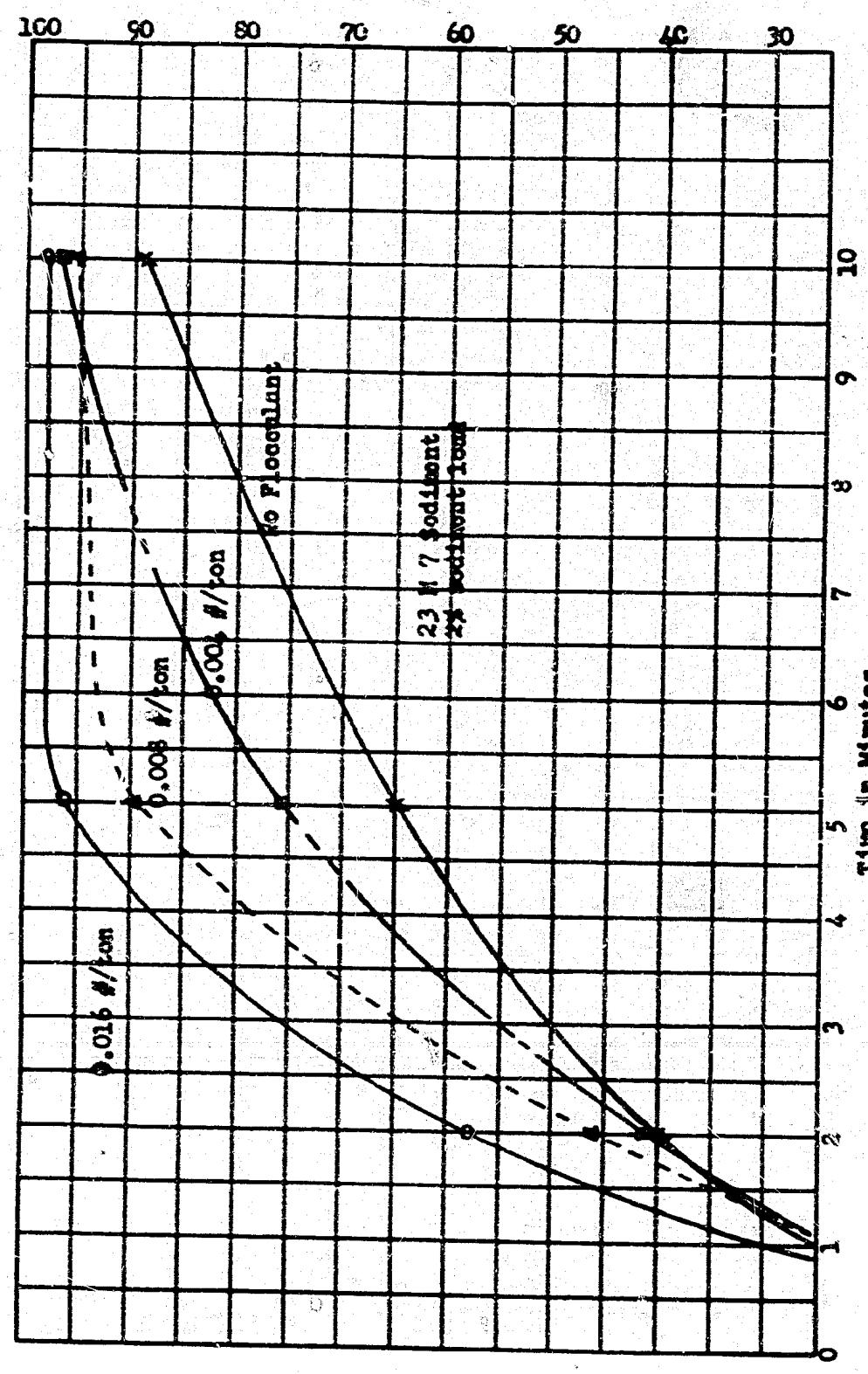
FIGURE 9



EFFECT OF TIME ON SETTLING EFFICIENCY

SEDIMENTATION STUDY
Using Flocculating Agents

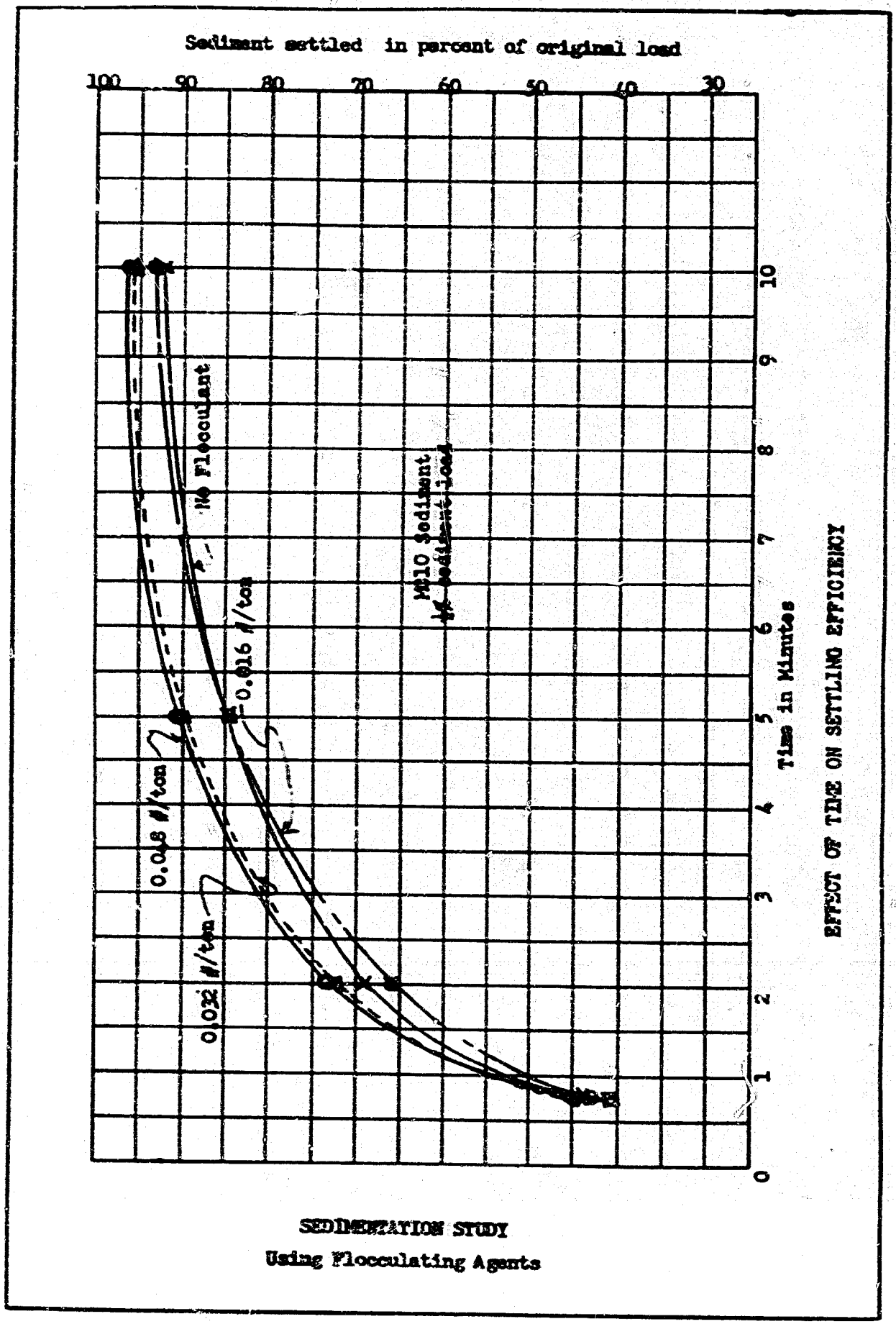
FIGURE 10



EFFECT OF TIME ON SETTLING EFFICIENCY

SEDIMENTATION STUDY
Using Flocculating Agents

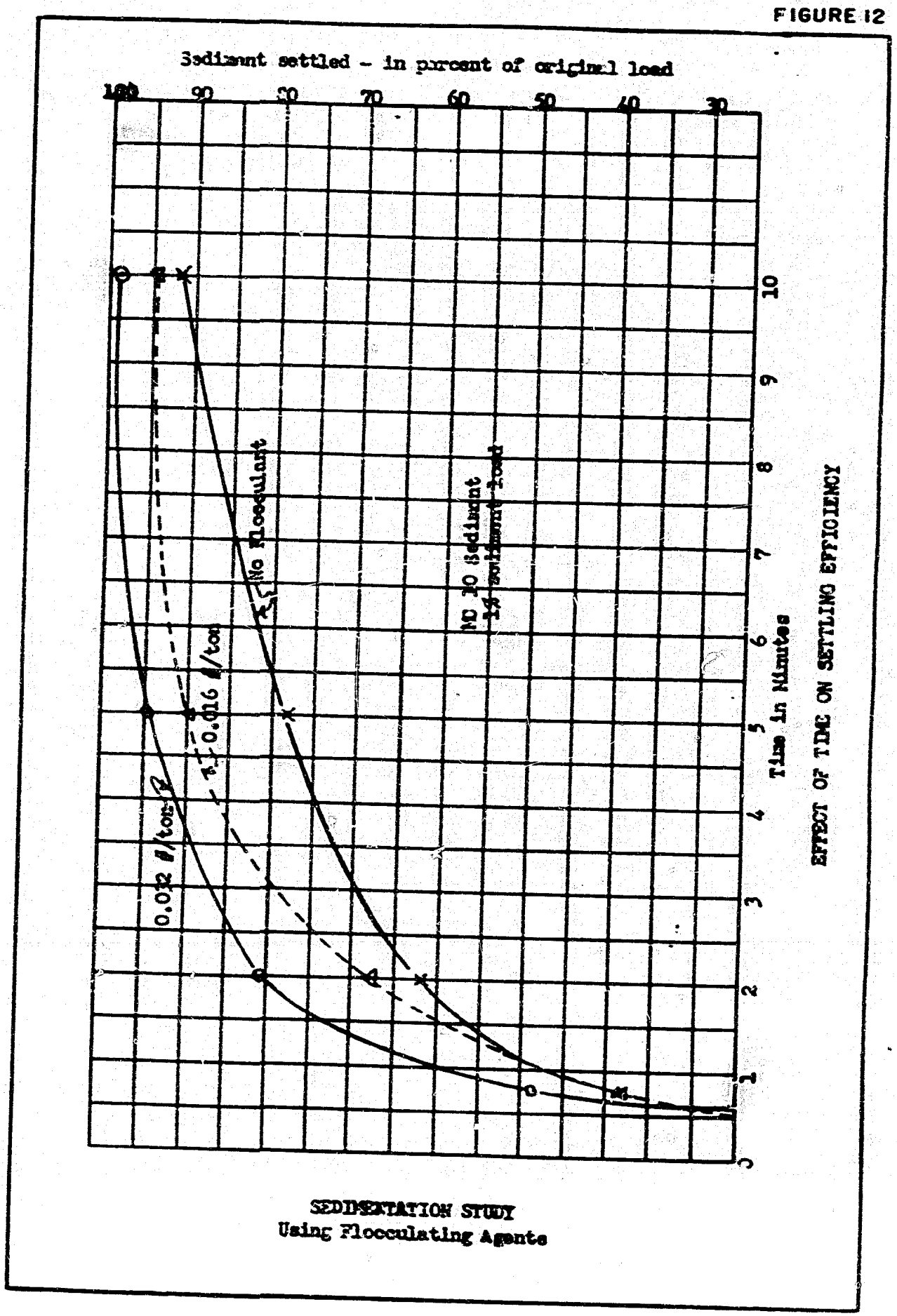
FIGURE II



SEDIMENTATION STUDY

Using Flocculating Agents

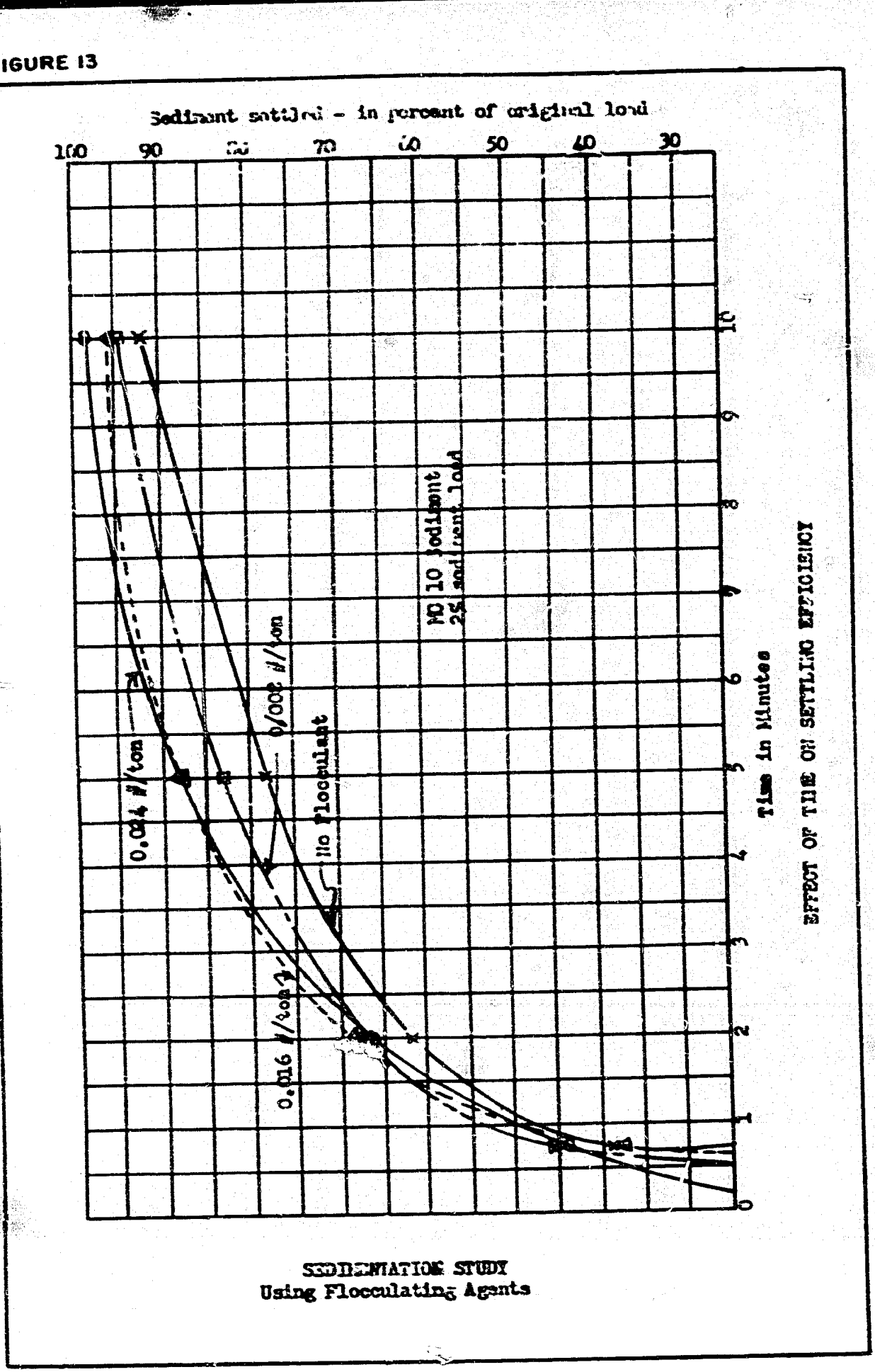
FIGURE 12



EFFECT OF TIME ON SETTLING EFFICIENCY

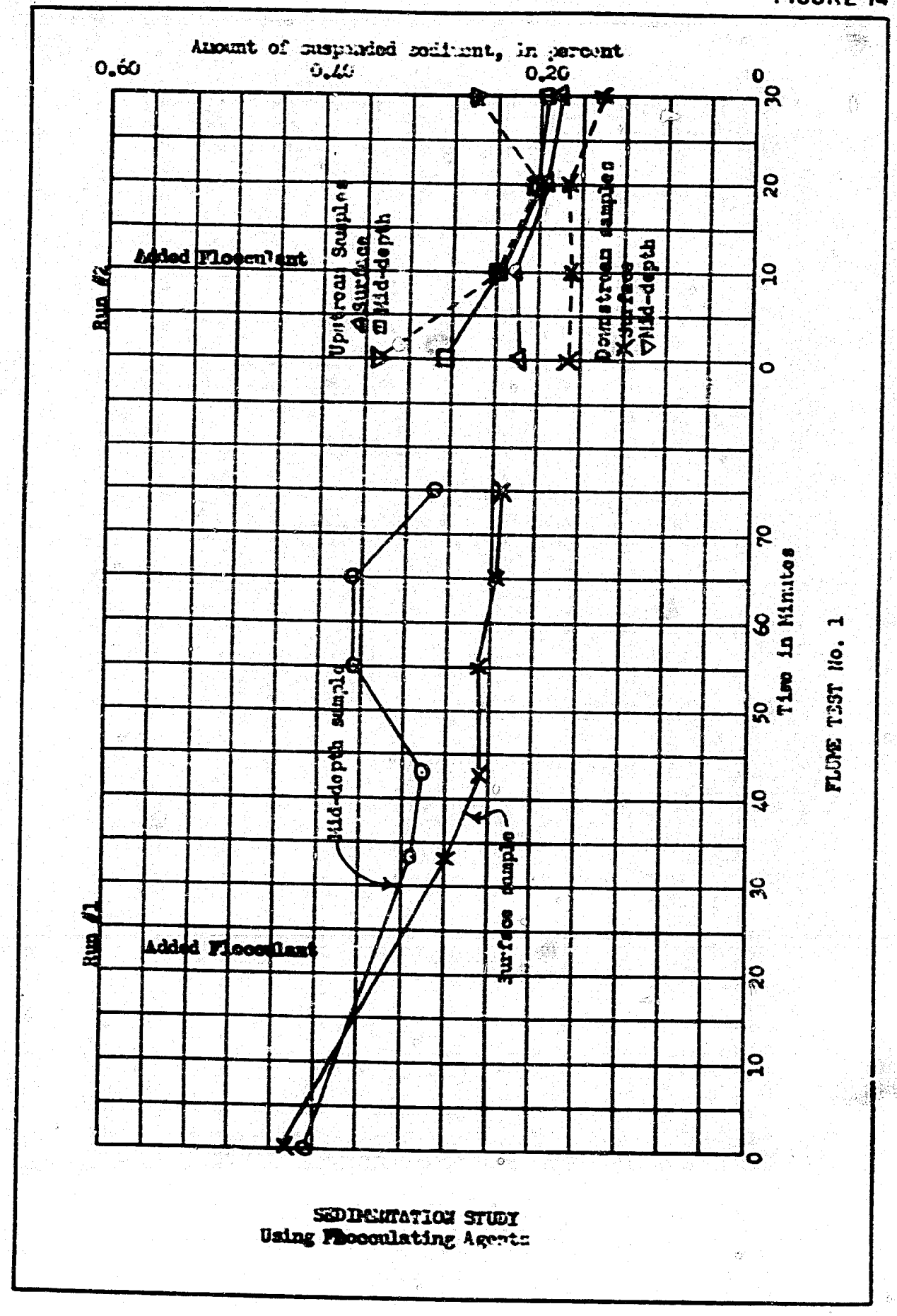
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 13



SEDIMENTATION STUDY
Using Flocculating Agents

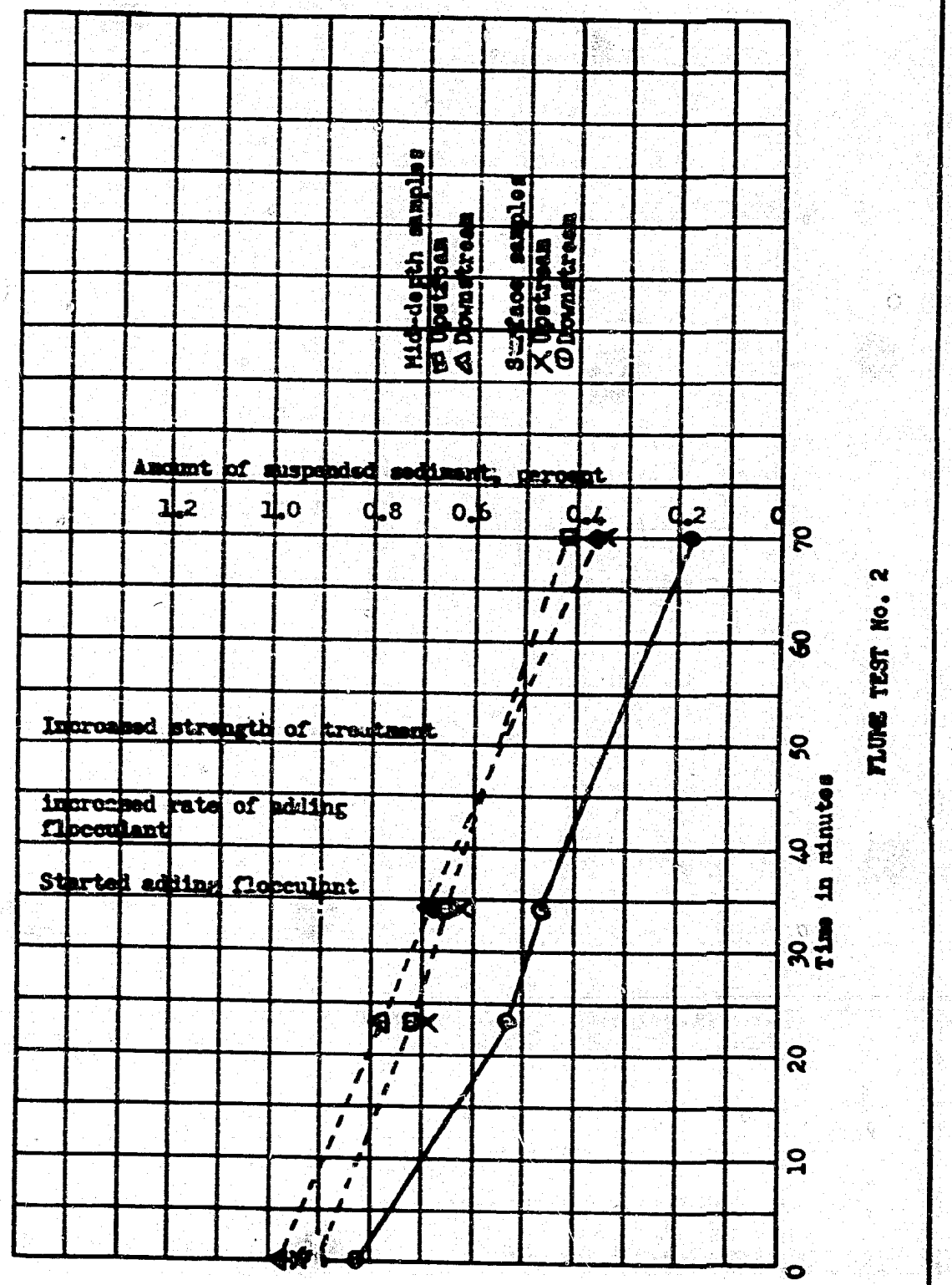
FIGURE 14



FLUME TEST No. 1

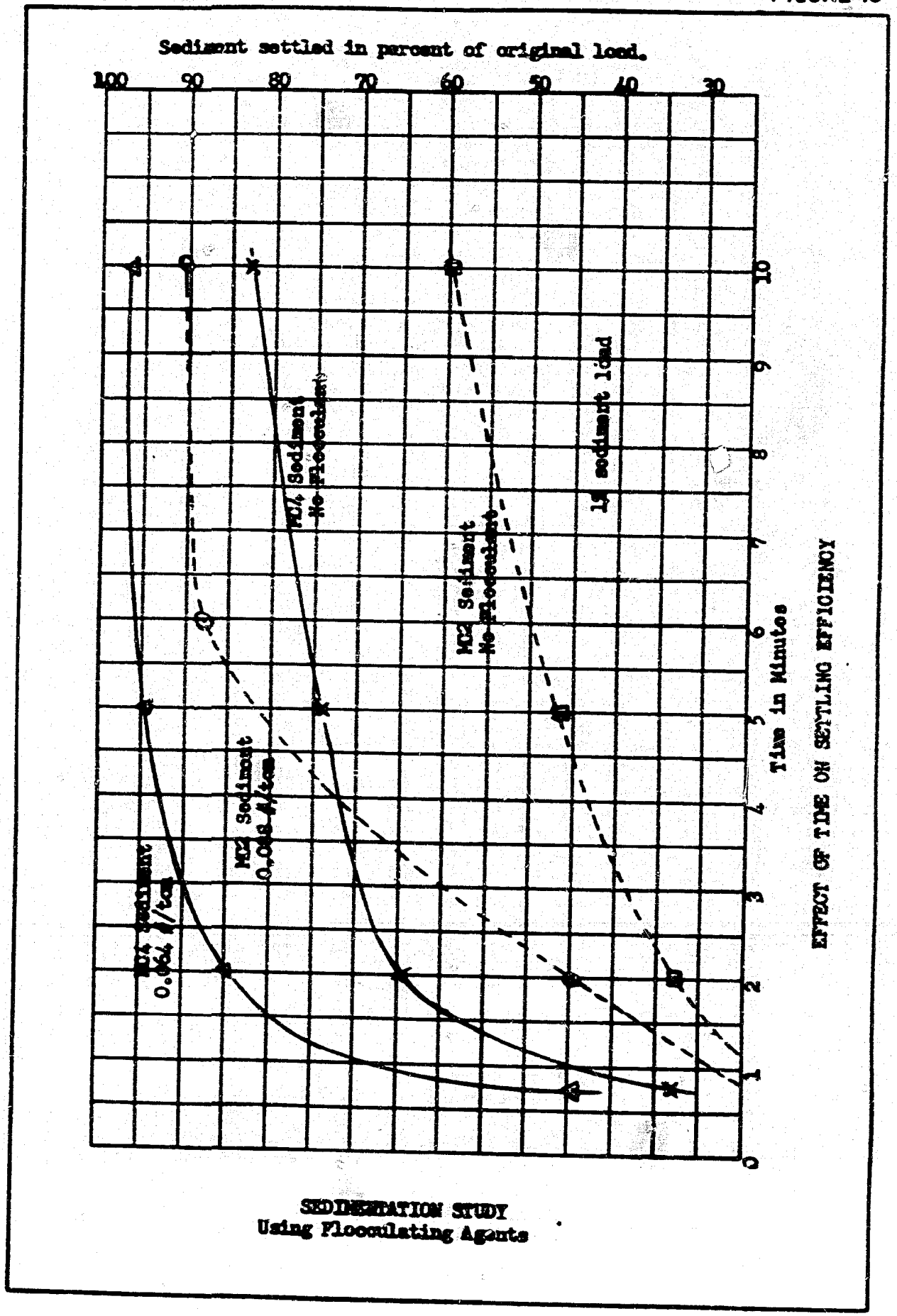
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 15



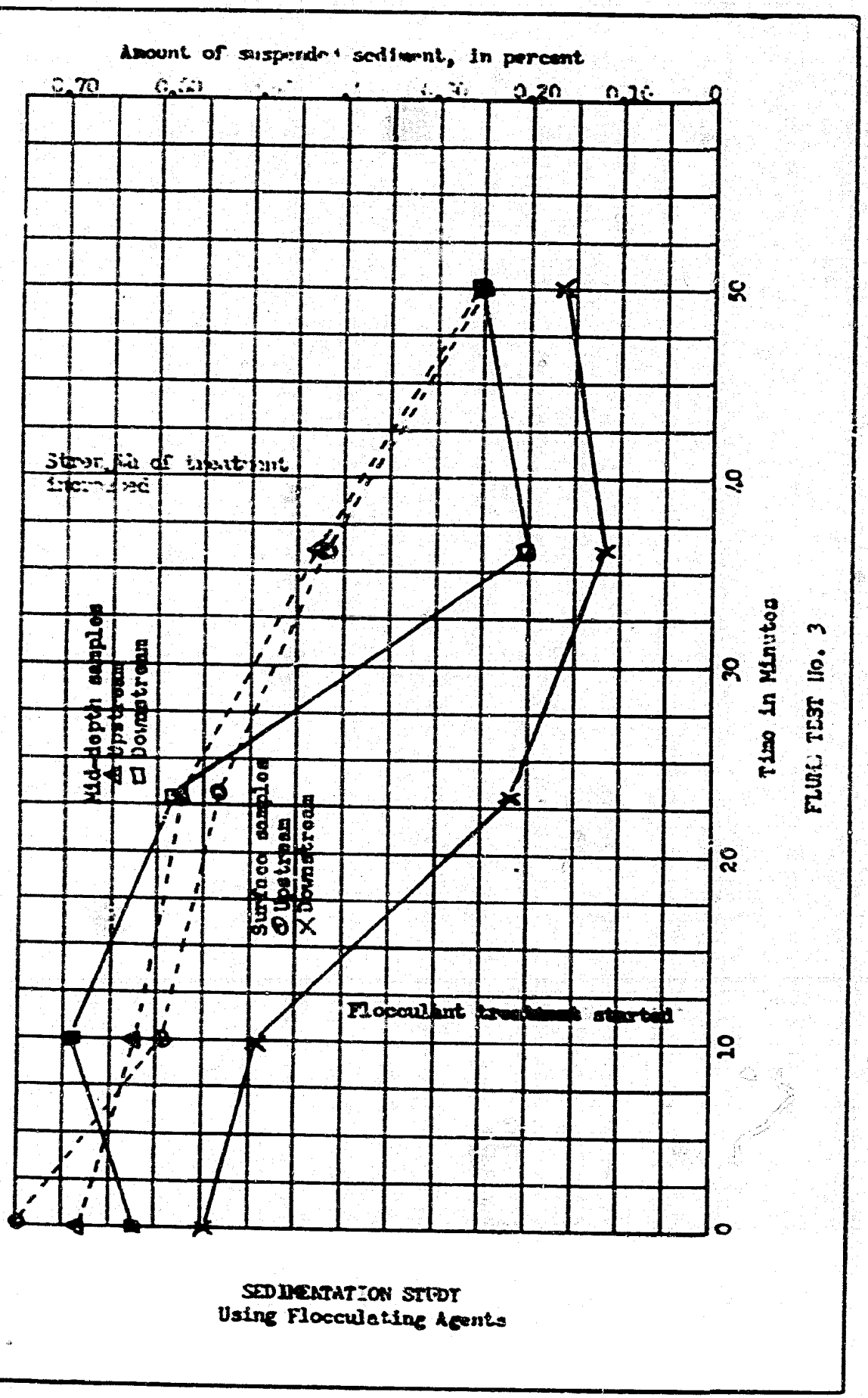
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 16



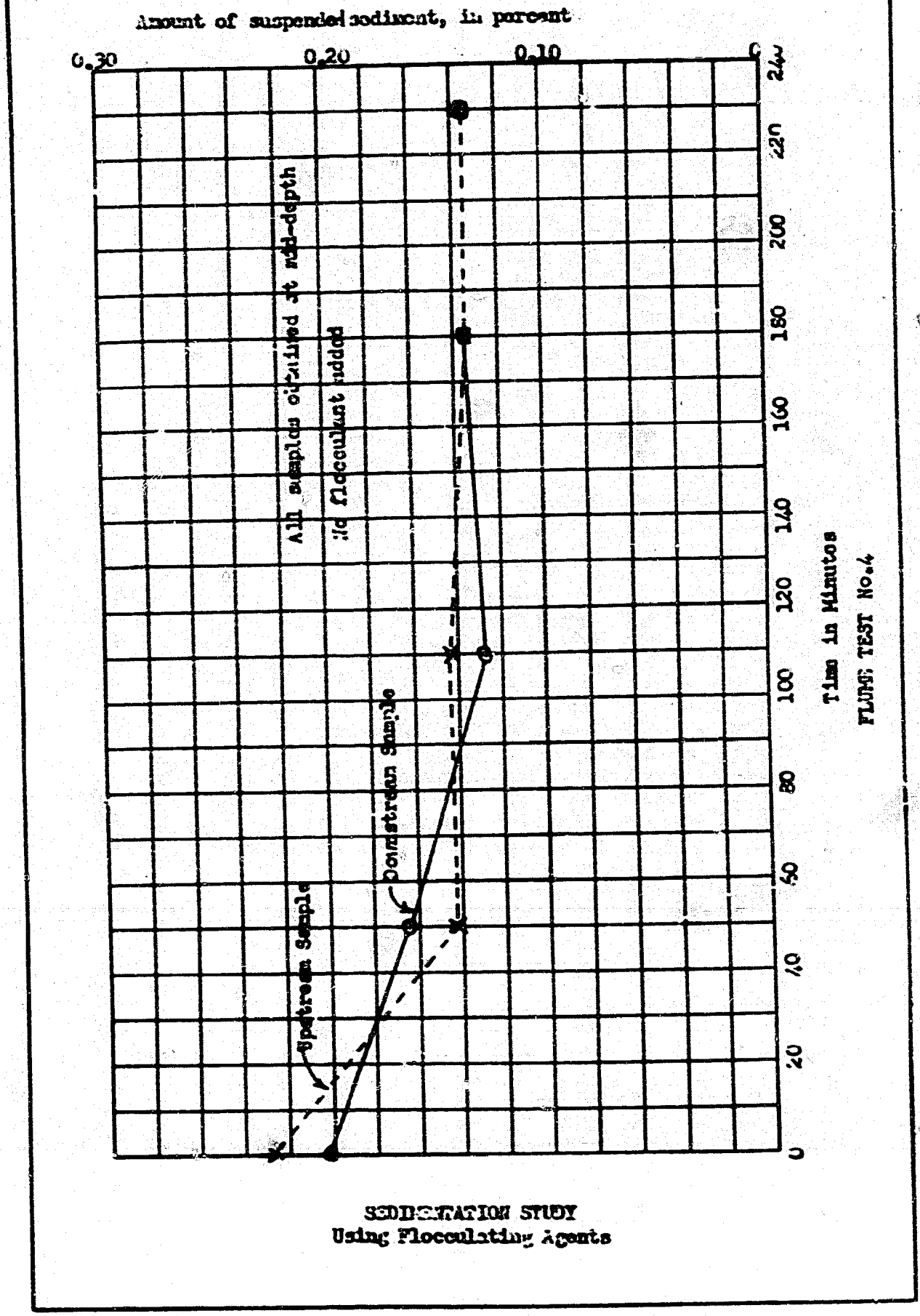
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 17



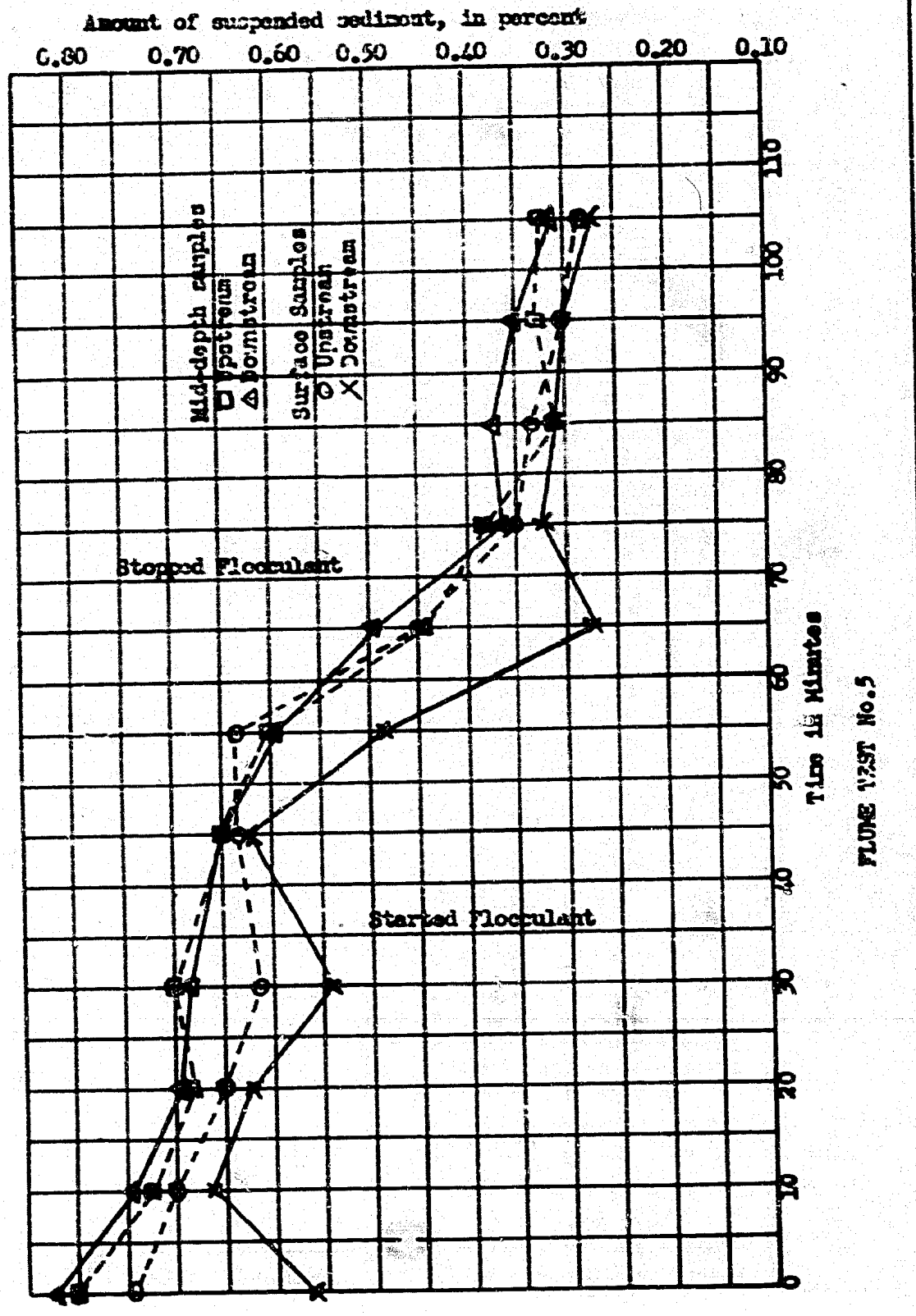
SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 18



SEDIMENTATION STUDY
Using Flocculating Agents

FIGURE 19



SEDIMENTATION STUDY
Using Flocculating Agents

Interior - Reclamation - Denver, Colo.